

ESTIMATES OF SITE POTENTIAL FOR DOUGLAS-FIR BASED ON SITE INDEX FOR SEVERAL SOUTHWESTERN HABITAT TYPES

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ABSTRACT.—Estimates of site potential for Douglas-fir based on measured site indexes in 450 stands are compared between 10 southwestern habitat types. Significant differences in site potential are found between the habitat types studied.

Site index is currently the most widely used method of evaluating site quality or potential productivity of forest lands in the United States (Jones 1969, Husch et al. 1972, Daubenmire 1976). Site index is based on the average heights of dominant and codominant trees at a specified index age (usually 50 or 100 years). Because stands of the index age are seldom encountered, site index curves are constructed to allow for estimation of site index for stands older or younger than the index age by interpolation between the curves. Site index curves describe the height growth of hypothetical trees of specified site indexes.

The use of habitat types (Daubenmire 1952) to classify forest vegetation is gaining acceptance by land managers and researchers in the western United States (Layser 1974, Pfister 1976, Pfister and Arno 1980). One of the primary uses of habitat types is in timber management. Habitat types are used to compare regeneration success, succession patterns, cutting methods, and timber productivity and to develop guidelines for collecting seed and planting nursery stock (Pfister and Arno 1980).

The use of habitat types to predict forest site productivity potential is proposed by several investigators. Differences in the rate of height growth by habitat type are demonstrated for several tree species (Daubenmire 1961, Deitschman and Greene 1965, Stanek 1966, Stage 1975, Hoffman 1976). Significant differences between site indexes are also shown for habitat types (Stanek 1966, Stage 1975, Hoffman 1976). Pfister et al. (1971, 1977) and Steele et al. (1981) use site index

curves and normal yield tables to estimate yield capability for habitat types in Montana and Idaho.

Southwestern forests are becoming more intensively managed for timber production than in the past. However, growth and productivity data are presently limited (Gottfried 1978). Habitat type classifications are recognized for these forests, but little information is available on the timber productivity potential for these habitat types (Moir and Ludwig 1979, Hanks et al. 1983, Alexander et al. 1984). Jones (1974) provides a summary of the silviculture of southwestern mixed conifer forests and emphasizes a need for improving their management based on the application of habitat types or stand types. This study provides additional quantitative data on site potential based on site index measurements for Douglas-fir for several recognized southwestern forest habitat types.

METHODS

Total height and age at diameter breast height were measured for two to six vigorously growing dominant or codominant Douglas-firs in 450 uneven-aged southwestern spruce-fir (31) or mixed conifer (419) stands from 1979 to 1985. Trees with visible signs of abiotic, insect, or disease damage were not selected as site trees in the stands. The following information was recorded for each stand: national forest, location (township, range, and section), elevation (nearest 100 feet), aspect (four cardinal directions), slope (nearest 5%), slope position (flat, bottom, ridge, slope) and

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TABLE 1. Southwestern spruce-fir and mixed conifer habitat types sampled.

Spruce-fir Habitat Types	
ABLA/LIBO:	<i>Abies lasiocarpa</i> / <i>Linnæa borealis</i> ² (<i>Abies lasiocarpa</i> / <i>Vaccinium scoparium</i> - <i>Linnæa borealis</i> ⁴)
ABLA/ EREX:	<i>Abies lasiocarpa</i> / <i>Erigeron eximius</i> ^{2,3} (<i>Abies lasiocarpa</i> / <i>Erigeron superbus</i> ⁴)
Mixed Conifer Habitat Types	
PIEN/SECA:	<i>Picea engelmannii</i> / <i>Senecio cardamine</i> ³ (<i>Picea pungens</i> - <i>Picea engelmannii</i> / <i>Senecio cardamine</i> ⁴)
PIEN/EREX:	<i>Picea engelmannii</i> / <i>Erigeron eximius</i> ³ (<i>Picea pungens</i> - <i>Picea engelmannii</i> / <i>Erigeron superbus</i> ⁴)
PIPU/EREX:	<i>Picea pungens</i> / <i>Erigeron eximius</i> ^{2,3} (<i>Picea pungens</i> - <i>Pseudotsuga menziesii</i> ⁴)
ABCO/ACGL:	<i>Abies concolor</i> / <i>Acer glabrum</i> ^{1,3} (<i>Abies concolor</i> - <i>Pseudotsuga menziesii</i> / <i>Acer glabrum</i> ⁴)
ABCO/FEAR:	<i>Abies concolor</i> / <i>Festuca arizonica</i> ^{4,5} (<i>Abies concolor</i> - <i>Pseudotsuga menziesii</i> / <i>Poa fendleriana</i> ⁴)
ABCO/QUGA:	<i>Abies concolor</i> / <i>Quercus gambelii</i> ^{1,2,3} (<i>Abies concolor</i> - <i>Pseudotsuga menziesii</i> / <i>Quercus gambelii</i> ⁴)
ABCO/BERE:	<i>Abies concolor</i> / <i>Berberis repens</i> ⁶ (<i>Abies concolor</i> - <i>Pseudotsuga menziesii</i> /[sparse] ⁴)
ABCO/EREX:	<i>Abies concolor</i> / <i>Erigeron eximius</i> ^{2,3} (<i>Abies concolor</i> - <i>Pseudotsuga menziesii</i> / <i>Erigeron superbus</i> ⁴)

¹ALEXANDER, B. G., JR., F. RONCO, JR., E. L. FITZHUGH, AND J. A. LUDWIG. 1984. A classification of forest habitat types of the Lincoln National Forest, New Mexico. USDA Forest Service, Gen. Tech. Rep. RM-104. 29 pp.

²DEVELICE, R. L., J. A. LUDWIG, W. H. MOIR, AND F. RONCO, JR. In preparation. A classification of forest habitat types of northern New Mexico and southern Colorado. USDA Forest Service, Gen. Tech. Rep. RM.

³FITZHUGH, E. L., W. H. MOIR, J. A. LUDWIG, AND F. RONCO. Forest habitat types in the Apache, Gila, and part of the Cibola national forests, Arizona and New Mexico. In preparation.

⁴MOIR, W. H., AND J. A. LUDWIG. 1979. A classification of spruce-fir and mixed conifer habitat types of Arizona and New Mexico. USDA Forest Service, Res. Pap. RM-207. 47 pp.

⁵The *Abies concolor*-*Pseudotsuga menziesii*/*Poa fendleriana* habitat type originally described by Moir and Ludwig (1979) is now considered to represent phase of the *Abies concolor*/*Festuca arizonica* habitat type described by Moir and Ludwig (1979). Personal communication with W. B. Moir, 1985.

⁶YOUNGBLOOD, A. P. In press. Coniferous forest habitat types of central and southern Utah. USDA Forest Service, Gen. Tech. Rep. INT.

TABLE 2. Mean Douglas-fir site indexes and standard deviations by habitat type.

Habitat type	Number of stands	Mean	Site potential class
PIEN/SECA	39	91.3 ± 9.6 A ^{1/}	High
ABCO/ACGL	69	89.5 ± 11.4 A	High
ABCO/FEAR	25	87.5 ± 8.2 A	High
PIPU/EREX	27	82.6 ± 10.2 B	Moderate
ABCO/EREX	52	81.2 ± 10.8 B	Moderate
ABCO/QUGA	92	76.9 ± 10.7 B	Moderate
PIEN/EREX	28	76.2 ± 17.0 B	Moderate
ABCO/BERE	87	74.5 ± 9.6 B	Moderate
ABLA/EREX	12	73.6 ± 10.7 BC	Moderate
ABLA/LIBO	19	67.3 ± 14.4 C	Low
TOTAL	450		

^{1/} One-way AOV, $p = 0.10$. Student-Newman-Kuels. Means followed by different letters are significantly different.

habitat type (Moir and Ludwig 1979, Alexander et al. 1984, Fitzhugh et al. unpublished, DeVelice et al. unpublished, Youngblood unpublished). A total of 10 habitat types were sampled (Table 1). Stands sampled were located in the Apache (216 stands), Coconino (9 stands), and Kaibab (23 stands) National

Forests, Arizona; the Carson (49 stands), Gila (9 stands), Lincoln (50 stands), and Santa Fe (58 stands) National Forests, New Mexico; and the San Juan National Forest, Colorado (36 stands).

Site indexes were determined from average height and age data for each stand using the Douglas-fir site index curves developed by Edminster and Jump (1976). Mean site index and standard deviation were calculated for each habitat type. A one-way analysis of variance, with $p = 0.10$, was used to compare mean site indexes among habitat types. The Student-Newman-Kuels test was applied to the analysis to show where significant differences occurred.

RESULTS

The 10 habitat types are divided into three site potential classes (high, moderate, and low) based on statistically significant differences in mean site indexes (Table 2). The PIEN/SECA (mean-91.3), ABCO/ACGL

(89.5), and ABCO/FEAR (87.6) habitat types are classified as high site potential habitat types for Douglas-fir. The ABLA/LIBO (mean-67.7) is classified as the low potential habitat type. The moderate site potential class includes the remaining six habitat types studied with mean site indexes ranging from 82.6 (PIPU-EREX) to 73.6 (ABLA/EREX). Mean site indexes for the ABLA/EREX and ABLA/LIBO habitat types were not significantly different, but they were classified into different site potential classes because the mean for the ABLA/LIBO habitat type was below 70 feet.

DISCUSSION

Site index is currently the most widely used method of evaluating site quality in the United States (Jones 1969, Husch et al. 1972). Several investigators note significant differences in site index between habitat types for several tree species (Stanek 1966, Roe 1967, Hoffman 1976). However, Daubenmire (1961) rejects the use of ponderosa pine site index curves for predicting potential productivity of habitat types in eastern Washington.

Our results indicate that the southwestern spruce-fir and mixed conifer habitat types sampled in this study can be grouped into three significantly different site quality classes for Douglas-fir. Hoffman (1976) also demonstrates significant differences in Douglas-fir site index between three habitat types in central Idaho.

In their descriptions of southwestern spruce-fir and mixed conifer habitat types, Moir and Ludwig (1979) give estimates of site quality for individual tree species for several habitat types. Their estimates are based on site index and height-age data. Our site index data supports Moir and Ludwig's site quality estimates for Douglas-fir in the PIEN/SECA (high potential), PIEN/EREX and PIPU/EREX (moderate potential) and the ABCO/BERE (usually moderate potential) habitat types. Our data also confirm their suggestion that the ABCO/ACGL habitat type has high Douglas-fir height growth potential.

Moir and Ludwig (1979) interpret heights of 75–100 feet in 100 years (breast height age) for the fastest growing Douglas-firs in the ABCO/QUGA habitat type to represent poor to moderate site quality, whereas we inter-

pret these data as representing moderate to high site quality for the Southwest. Our site index data for this habitat type basically correspond to that of Moir and Ludwig's, except the range of site indexes is wider in our study.

Moir and Ludwig (1979) do not present Douglas-fir site quality estimates for three of the habitat types sampled in this study. Based on our site index data, site quality for Douglas-fir is moderate for the ABCO/EREX and ABLA/EREX habitat types and high for the ABCO/FEAR habitat type.

Several investigators discuss the difficulties of using site index for estimating site potential in uneven-aged stands (Stage 1963, Jones 1969, Curtis 1976, Daubenmire 1976). Steele et al. (1981, 1983) use site indexes and normal yield tables to estimate productivity potential for habitat types in Montana and Idaho. However, normal yield tables for Douglas-fir in the Southwest are not available, and we do not feel the use of yield tables from other regions would be valid for the Southwest. The development of separate site curves for different habitat types should improve the accuracy of site index as an estimate of site quality. However, this approach may not solve the problems related to using site index in uneven-aged stands such as early suppression of shade tolerant species (Vincent 1961, Curtis 1976). We agree with the suggestion of Steele et al. (1983) that the development and subsequent validation of growth and yield simulation models using growth coefficients based on habitat types (Stage 1973, 1975) will improve productivity estimates for habitat types.

LITERATURE CITED

- ALEXANDER, B. C., F. RONCO, L. FITZHUGH, AND J. LUDWIG. 1984. A classification of forest habitat types of the Lincoln National Forest, New Mexico. USDA Forest Service, Gen. Tech. Rep. RM-104. 29 pp.
- CURTIS, R. O. 1976. Uneven-aged silviculture and management in the United States. USDA Forest Service, Proceedings of In-Service Workshops, Morgantown, West Virginia, and Redding, California, Timber Management Research, Washington, D.C.
- DAUBENMIRE, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on the concepts of vegetation classification. *Ecol. Monogr.* 22: 301–330.
- _____. 1961. Vegetative indicators of rate of height growth in ponderosa pine. *For. Sci.* 7: 24–34.
- _____. 1976. The use of vegetation in assessing the productivity of forest lands. *Bot. Review* 42: 115–143.

- DEITSCHMAN, G. H., AND A. W. GREENE. 1965. Relations between western white pine site index and tree height of several associated species. USDA Forest Service, Res. Pap. INT-22. 27 pp.
- DEVELICE, R. L., J. A. LUDWIG, W. H. MOIR, AND F. RONCO, JR. In preparation. A classification of forest habitat types of northern New Mexico and southern Colorado. USDA Forest Service, Gen. Tech. Rep. RM.
- EDMINSTER, C. B., AND L. H. JUMP. 1976. Site index curves for Douglas-fir in New Mexico. USDA Forest Service, Res. Note RM-326. 3 pp.
- FITZHUGH, E. L., W. H. MOIR, J. A. LUDWIG, AND F. RONCO, JR. In preparation. Forest habitat types in the Apache, Gila, and part of the Cibola national forests, Arizona and New Mexico. In preparation.
- GOTTFRIED, G. J. 1978. Five-year growth and development in a virgin Arizona mixed conifer stand. USDA Forest Service, Res. Pap. RM-203. 22 pp.
- HANKS, J. P., L. FITZHUGH, AND S. R. HANKS. 1983. A habitat type classification system for ponderosa pine forests of northern Arizona. USDA Forest Service, Gen. Tech. Rep. RM-97. 22 pp.
- HOFFMAN, L. J. 1976. Height growth of Douglas-fir in relation to habitat types in northern Idaho. Unpublished thesis, University of Idaho, Moscow, Idaho. 30 pp.
- HUSCH, B., C. MILLER, AND T. W. BEERS. 1972. Forest mensuration. Ronald Press Company, New York. 410 pp.
- JONES, J. R. 1969. Review and comparison of site evaluation methods. USDA Forest Service, Res. Pap. RM-75. 19 pp.
- _____. 1974. Silviculture of southwestern mixed conifer and aspen: the status of our knowledge. USDA Forest Service, Res. Pap. RM-122. 44 pp.
- LAYSER, E. F. 1974. Vegetation classification: its application to forestry in the northern Rocky Mountains. *J. For.* 72: 354-357.
- MOIR, W., AND J. LUDWIG. 1979. Classification of spruce-fir and mixed conifer habitat types of Arizona and New Mexico. USDA Forest Service, Res. Pap. RM-207. 47 pp.
- PFISTER, R. D. 1976. Land capability assessment by habitat types. Pages 312-335 in *America's renewable resource potential—1975: the turning point*. Proceedings of the 1975 National Convention Society of American Foresters, Washington, D.C.
- PFISTER, R. D., AND S. ARNO. 1980. Classifying forest habitat types based on potential climax vegetation. *For. Sci.* 26: 52-70.
- PFISTER, R. D., B. KOVALCHIK, S. ARNO, AND R. PRESBY. 1977. Forest habitat types of Montana. USDA Forest Service, Gen. Tech. Rep. INT-34. 174 pp.
- PFISTER, R. D., J. SCHMAUTZ, D. ON, AND C. BROWN. 1971. Management implication by habitat types. USDA Forest Service, Northern Region Training Manual, Mimeograph. 30 pp.
- ROE, A. L. 1967. Productivity indicators in western larch forests. USDA Forest Service, Res. Note INT-59. 4 pp.
- STAGE, A. R. 1963. A mathematical approach to the polymorphic site index curves for grand fir. *For. Sci.* 9: 167-180.
- _____. 1973. Prognosis model for stand development. USDA Forest Service, Res. Pap. INT-137. 32 pp.
- _____. 1975. Prediction of height increments for models for forest growth. USDA Forest Service, Res. Pap. INT-164. 20 pp.
- STANEK, W. 1966. Relative quality of the major forest association of the southern British Columbia interior for growth of lodgepole pine, Engelmann spruce, Douglas-fir, and alpine fir. *For. Chron.* 42: 306-313.
- STEELE, R., S. V. COOPER, D. M. ONDOV, D. W. ROBERTS, AND R. D. PFISTER. 1983. Forest habitat types of eastern Idaho—western Wyoming. USDA Forest Service, Gen. Tech. Rep. INT-144. 122 pp.
- STEELE, R., R. D. PFISTER, R. A. RYKER, AND J. A. KITTAMS. 1981. Forest habitat types of central Idaho. USDA Forest Service, Gen. Tech. Rep. INT-114. 138 pp.
- VINCENT, A. B. 1961. Is height/age a reliable index of site? *For. Chron.* 37: 144-150.
- YOUNGBLOOD, A. P. In press. Coniferous forest habitat types of central and southern Utah. USDA Forest Service, Gen. Tech. Rep. INT.